

JAPAN

EDICT OF GOVERNMENT

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JIS B 9704-2 (2008) (English): Safety of machinery -- Electro-sensitive protective equipment -- Part 2: Particular requirements for equipment using active opto-electronic protective devices (AOPDs)

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*The citizens of a nation must
honor the laws of the land.*

Fukuzawa Yukichi

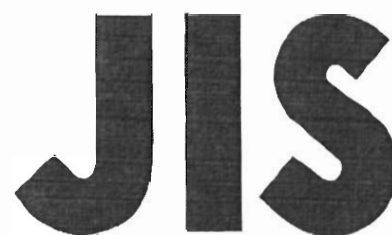
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INDUSTRIAL
STANDARD

Translated and Published by
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JIS B 9704-2 : 2008

(IEC 61496-2 : 2006)

(JMF)

**Safety of machinery—
Electro-sensitive protective
equipment—Part 2 : Particular
requirements for equipment using
active opto-electronic protective
devices (AOPDs)**

ICS 13.110; 29.260.99

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Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Health, Labour and Welfare and Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by The Japan Machinery Federation (JMF) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14. Consequently **JIS B 9704-2:2000** is replaced with this Standard.

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Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have technical properties. The relevant Ministers and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have the said technical properties.

JIS B 9704 consists of the following parts under the general title “*Safety of machinery—Electro-sensitive protective equipment*”;

Part 1: General requirements and tests

Part 2: Particular requirements for equipment using active opto-electronic protective devices (AOPDs)

Part 3: Particular requirements for Active Opto-electronic Protective Devices responsive to Diffuse Reflection (AOPDDR)

Safety of machinery—Electro-sensitive protective equipment—

Part 2 : Particular requirements for equipment using active opto-electronic protective devices (AOPDs)

Introduction

This Japanese Industrial Standard has been prepared based on the second edition of **IEC 61496-2** published in 2006 without modifying the technical contents.

The portions given dotted underlines and Annex JA are the matters not stated in the original International Standard.

Electro-sensitive protective equipment (hereafter referred to as “ESPE”) is applied to machinery that presents a risk of personal injury. It provides protection by causing the machine to revert to a safe condition before a person can be placed in a hazardous situation. General requirements and tests for ESPE are specified in **JIS B 9704-1** (hereafter referred to as “Part 1”).

ESPE is classified into several types based on various detection principles. This Standard provides particular requirements for the design, construction and testing of ESPE for the safeguarding of machinery, employing active opto-electronic protective devices (hereafter referred to as “AOPDs”) for the sensing function.

This Standard is to be used in conjunction with Part 1. This Standard supplements or modifies the corresponding clauses in Part 1. Where a particular clause or subclause of Part 1 is not mentioned in this Standard, that clause or subclause applies as far as is reasonable. Where this part states “addition” or “replacement”, the relevant text of Part 1 is to be adapted accordingly. All the clauses of **JIS B 9704** Part 1 and Part 2 applicable to the equipment using AOPDs are listed in Annex JA.

This Standard specifies type 2 and type 4 ESPE employing AOPDs but not type 1 and type 3 ESPE.

Each type of machine presents its own particular hazards, and it is not the purpose of this Standard to recommend the manner of application of the ESPE to any particular machine. The application of the ESPE should be a matter for agreement between the equipment supplier, the machine user and the enforcing authority; in this context, attention is drawn to the relevant guidance established, for example, **JIS B 9700-1** or **JIS B 9700-2**.

1 Scope

(Replacement. This clause of Part 1 is replaced by the following:)

This Standard specifies requirements for the design, construction and testing of ESPE designed specifically to detect persons as part of a safety-related system, employing AOPDs for the sensing function. Special attention is directed to features which ensure that an appropriate safety-related performance is achieved. An ESPE may include optional safety-related functions, the requirements for which are given in Annex A.

This Standard does not specify the dimensions or configurations of the detection zone and its disposition in relation to hazardous parts for any particular application, nor what constitutes a hazardous state of any machine. It is restricted to the functioning of the ESPE and how it interfaces with the machine.

Excluded from this Standard are AOPDs employing radiation at wavelengths outside the range 400 nm to 1 500 nm.

This Standard may be relevant to applications other than those for the protection of persons, for example, the protection of machinery or products from mechanical damage. In those applications, additional requirements may be necessary, for example, when the materials that are to be recognized by the sensing function have different properties from those of persons.

This Standard does not deal with electromagnetic compatibility (EMC) emission requirements.

NOTE : The International Standard corresponding to this Standard is as follows.

IEC 61496-2:2006 *Safety of machinery—Electro-sensitive protective equipment—Part 2: Particular requirements for equipment using active opto-electronic protective devices (AOPDs)* (IDT)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21**.

2 Normative references

(Addition:)

JIS B 9715:2006 *Safety of machinery—Positioning of protective equipment with respect to the approach speeds of parts of the human body*

NOTE : Corresponding International Standards: ISO 13855:2002 *Safety of machinery—Positioning of protective equipment with respect to the approach speeds of parts of the human body* (IDT)

JIS C 6802 *Safety of laser products*

NOTE : Corresponding International Standards: IEC 60825-1 *Safety of laser products—Part 1: Equipment classification and requirements* and user's guide (IDT)

TS B 62046:2006 *Safety of machinery—Application of protective equipment to detect the presence of persons*

NOTE : Corresponding International Standards: IEC/TS 62046:2004 *Safety of machinery—Application of protective equipment to detect the presence of persons* (IDT)

EN 471:2003 *High-visibility warning clothing for professional use—Test methods and requirements*

3 Terms and definitions

(Addition:)

3.201 active opto-electronic protective device (AOPD)

device whose sensing function is performed by opto-electronic emitting and receiving elements detecting the interruption of optical radiations generated, within the device, by an opaque object present in the specified detection zone (or for a light beam device, on the axis of the light beam)

NOTE : "Active" means that the device itself discharges the energy for detection (irradiation light).

3.202 beam centre-line

optical path joining the optical centre of an emitting element to the optical centre of the corresponding receiving element that is intended to respond to light from that emitting element during normal operation

NOTE 1 The optical axis of a light beam is not always on the beam centre-line.

NOTE 2 Physical displacement of the beam centre-line may occur as a consequence of normal operation (for example, by the use of a motor-driven mirror).

NOTE 3 For an AOPD that operates on a retro-reflective technique, the optical path is defined by the retro-reflector target together with the emitting and receiving elements.

3.203 effective aperture angle (EAA)

maximum angle of deviation from the optical alignment of the emitting element(s) and the receiving element(s) within which the AOPD continues in normal operation

3.204 light beam device

single light beam device or a multiple light beam device

- **single light beam device**: AOPD comprising one emitting element and one receiving element, where a detection zone is not specified by the supplier;
- **multiple light beam device**: AOPD comprising multiple emitting elements and corresponding receiving elements, and where a detection zone is not specified by the supplier

3.205 light curtain

AOPD comprising an integrated assembly of one or more emitting element(s) and one or more receiving element(s) forming a detection zone with a detection capability specified by the supplier

NOTE : A light curtain with a large detection capability is sometimes referred to as a light grid.

3.206 test piece

opaque cylindrical element used to verify the detection capability of the AOPD

3.207 monitored blanking

configuration of the detection capability and/or detection zone in such a way that the presence of an object(s) within a defined part of the detection zone will not cause an OFF-state of the output signal switching device(s) [hereafter referred to as "OSSD(s)"] but the absence (or, in some cases, a change in size or location) of the object will cause the OSSD(s) to go to the OFF-state

3.3 detection capability

(Replacement:)

dimension representing the diameter of the test piece which:

- for a light curtain, will actuate the sensing device when placed in the detection zone;
- for a single light beam device, will actuate the sensing device when placed in the beam centre-line;
- for a multiple light beam device, will actuate the sensing device when placed in any beam centre-line

NOTE 1 Can also be used to mean the ability to detect a test piece of the specified diameter.

NOTE 2 "A large detection capability" means that the size of detectable element is large and not that the detection capability is superior.

In this Standard, detection probability is not considered. The test piece which has diameter corresponding to the detection capability should be 100 % detected.

4 Functional, design and environmental requirements

(This clause of Part 1 is applicable except as follows:)

4.1 Functional requirements

4.1.2 Sensing function

(Replacement:)

4.1.2.1 General

The sensing function shall be effective over the detection zone specified by the supplier. No adjustment of the detection zone, detection capability or blanking function shall be possible without the use of a key, key-word or tool.

The sensing device of a light curtain shall be actuated and the OSSD(s) shall go to the OFF-state when a test piece in accordance with 4.2.13 is placed anywhere within the detection zone either static (at any angle) or moving (with the axis of the cylinder normal to the plane of the detection zone), at any speed between 0 m/s and 1.6 m/s.

The sensing device of a light beam device shall be actuated and the OSSD(s) shall go to the OFF-state when a test piece in accordance with 4.2.13 is present in the beam centre-line, at any point throughout the operating distance¹⁾, with the axis of the cylinder normal to the axis of the beam.

Note ¹⁾ “An operating distance” means the distance between the emitter assembly and the receiver assembly. The minimum (maximum) operating distance means the minimum (maximum) distance within which AOPD is normally operable. The range of operating distance means the range between the minimum operating distance and the maximum operating distance within which AOPD is normally operable.

When the OSSD(s) go to the OFF-state, they shall remain in the OFF-state while the test piece is present in the detection zone (or light beam) or for at least 80 ms, whichever is greater.

NOTE : The purpose of this requirement is to ensure that the OSSD(s) go to the OFF-state when a person or part of a person passes through the detection zone or light beam. Based on a dimension of 150 mm and a walking speed of 1.6 m/s, a minimum OFF time of 80 ms was determined to be adequate.

Where the supplier states that an AOPD can be used to detect objects moving at speeds greater than 1.6 m/s, the above requirements shall be met at any speed up to and including the stated maximum speed(s).

4.1.2.2 Optical performance

The AOPD shall be designed and constructed to:

- a) limit the possibility of failure to danger resulting from extraneous reflections [for example, for operating range up to 3 m, see figure 1 ²⁾];

Note ²⁾ This means that the failure to danger resulting from a reflective surface existing in the outside of limit area is prevented by diminishing any reflective surfaces in the limit area shown in figure 1.

- b) limit the misalignment at which normal operation is possible;
- c) limit the possibility of malfunction during exposure to extraneous light in the range of 400 nm to 1 500 nm;
- d) control the size of the emitted beam to minimize the effects on other equipment (AOPD).

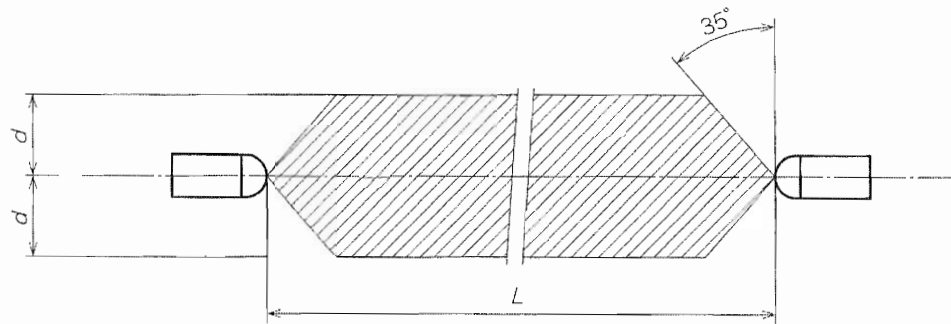
One method of achieving these requirements is by ensuring that the effective aperture angle of each emitting and each receiving element does not exceed the values given in figure 2. When this method is used, the requirements are met when the AOPD conforms to the tests in **5.2.9.2** and Annex D.

There are other technical means alternative to the restriction of the EAA to achieve equivalent performance for the characteristics in items **a)**, **b)**, **c)** and **d)** above. In such cases, the requirements are met when the AOPD conforms to the tests in **5.2.9.2** and Annex E.

Acceptable optical performance shall be verified by passing the appropriate tests of **5.2.9** and **5.4**.

If the AOPD is intended to provide protection when mounted very close to a reflective surface (i.e. inside the shaded area of figure 1), the AOPD shall be designed in such a manner that no optical bypassing can occur on the reflective surfaces. For such a device, an EAA much less than 2.5° (for example, less than 0.1°) can be necessary.

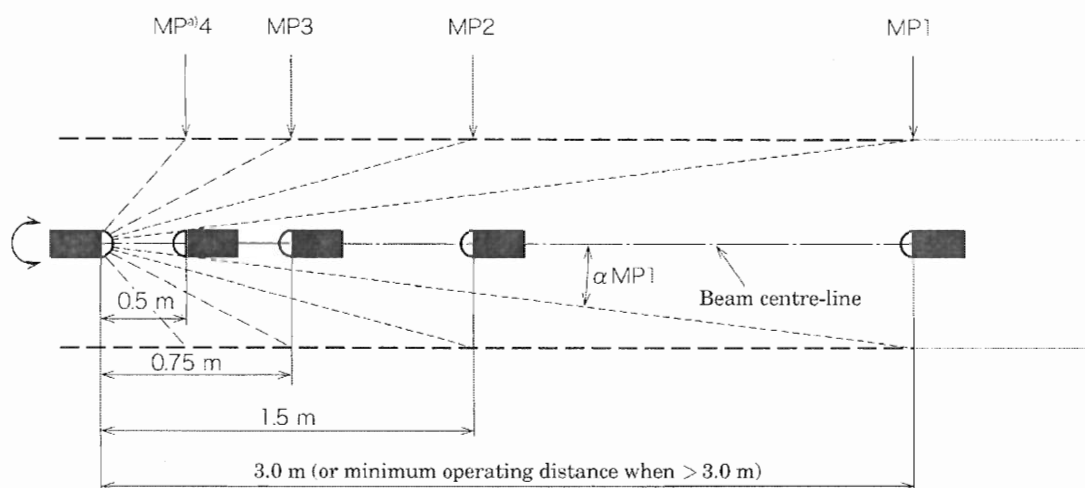
In this case, figures 1 and 2 do not apply and the limits of protection against optical bypassing shall be as specified by the manufacturer.



Unit: mm

| Type of ESPE | d | L |
|--------------|-----|--------------|
| Type 4 | 131 | 250 to 3 000 |
| Type 2 | 262 | 500 to 3 000 |

Figure 1 Limit area for the protection against the risk of beam bypass



| | α Limit values (°) | | | |
|--|---------------------------|-----|------|------|
| | MP1 | MP2 | MP3 | MP4 |
| Type 2 AOPD | 5 | 10 | 19.3 | 27.7 |
| Type 4 AOPD | 2.5 | 5 | 10 | 14.7 |
| Note ^{a)} MP: measuring point | | | | |

NOTE 1 The EAA should be determined according to 5.2.9.2.

NOTE 2 Measurements should be carried out at each of the measuring points MP1 to MP4 within the range of the operating distance specified by the supplier (or if minimum distance is greater than 3.0 m, at the minimum operating distance only).

Example : If the range of operating distance is within 1 m to 3.5 m, measurement should be carried out at points MP2 (1.5 m) and MP1 (3.0 m), but not at MP4 (0.5 m) and MP3 (0.75 m). Measurement at point 1.0 m is also recommended. If the range of operating distance is within 4 m to 10 m, measurement should be carried out only at point 4.0 m.

NOTE 3 The limit values for other distances than MP1, MP2, MP3 and MP4 can be calculated using the formula:

$$\alpha = \arctan (d/L)$$

where $d = 262$ mm (for Type 2)

or $d = 131$ mm (for Type 4)

and L is the distance between emitter and receiver (or DUT and retro-reflector target).

NOTE 4 For retro-reflector systems, the value of α is one-half of the value shown in the table above.

Figure 2 Measurement of the effective aperture angle (EAA)

4.1.2.3 Additional requirements for an AOPD using retro-reflective techniques

An AOPD using retro-reflective techniques where the light beam traverses the detection zone more than once (over the same path) shall not fail to danger if a reflective

object (for example, reflective clothes) is placed at any position in the detection zone and shall not be bypassed by an easily available reflector (for example, mirror).

NOTE 1 The use of mirrors to return the light beam is not considered to be a retro-reflective technique.

Retro-reflection means the reflection in which radiation is returned in directions close to the opposite of the direction from which it came, this property being maintained over wide variations of the direction of the incident rays. Retro-reflector means a surface of device from which most of the reflected radiation is retro-reflected (see JIS Z 8113). In this Standard, it indicates the retro-reflector as the component of AOPD.

The OSSD(s) of a single light beam device shall go to, and remain in, the OFF-state when a reflective object of a size greater than, or equal to, the diameter and length of the test piece (see 4.2.13) is placed in the beam at any position as specified in 5.2.1.1.

The reflective objects considered shall consist of:

- the retro-reflector target;
- a retro-reflecting material conforming to the requirements for retro-reflection of EN 471 class 2 or equivalent;

NOTE 2 Table 5 in EN 471 defines the minimum coefficient of retro-reflection for class 2 material as 330 cd lx m^{-2} with an entrance angle of 5° and an observation angle of 0.2° ($12'$).

- a mirror-type reflective surface having a reflection factor greater than, or equal to, 90 % at the operating wavelength, for example polished chrome plating or polished aluminium;
- a diffuse reflective surface, for example, white paper.

Under normal operating conditions the OSSD(s) of a light curtain and of a multiple light beam device using retro-reflective techniques shall go to and remain in the OFF-state when an identical reflector is placed as close as practicable in front of the sensing surface of the emitting/receiving element(s).

4.1.2.4 Additional requirements for an AOPD using emitters and receivers in the same assembly

Under normal operating conditions the OSSD(s) of an AOPD shall go to, and remain in, OFF-state when a reflective object whose size is greater than, or equal to, the diameter and length of the test piece is placed normal to the optical axes anywhere within the detection zone.

NOTE 1 This subclause does not apply to an AOPD using retro-reflective techniques.

The reflective objects considered shall consist of

- a retro-reflecting material conforming to the requirements for retro-reflection of EN 471 class 2 or equivalent;

NOTE 2 Table 5 in EN 471 defines the minimum coefficient of retro-reflection for class 2 material as 330 cd lx m^{-2} with an entrance angle of 5° and an observation angle of 0.2° ($12'$).

- a mirror-type reflective surface having a reflection factor greater than or equal to 90 % at the operating wavelength, for example, polished chrome plating or polished aluminium;
- a diffuse reflective surface, for example, white paper.

4.2 Design requirements

4.2.2 Fault detection requirements

4.2.2.3 Particular requirements for a type 2 ESPE

(Replacement of first paragraph:)

A type 2 ESPE shall have a means of periodic test to reveal a failure to danger (for example, loss of sensing unit detection capability, response time exceeding that specified). The test shall verify that each light beam operates in the manner specified by the supplier. Where the periodic test is intended to be initiated by an external (for example, machine) safety-related control system, the ESPE shall be provided with suitable input facilities (for example, terminals).

4.2.12 Integrity of the AOPD detection capability

(Addition:)

The design of the AOPD shall be such that the AOPD detection capability remains less than, or equal to, the value stated by the supplier when the AOPD is operated under any and all combinations of the following:

- any condition within the specification of the supplier;
- the environmental conditions specified in 4.3 (of Part 1 and this Standard);
- at the limits of alignment and/or adjustment.

If a single fault (as specified in Annex B), which under normal operating conditions (see 5.1.2.1 of Part 1) would not result in a loss of AOPD detection capability but, when occurring with a combination of the conditions specified above, would result in such a loss, that fault together with that combination of conditions shall be considered as a single fault, and the AOPD shall respond to such a single fault as required in 4.2.2. An example of a method for determining detection capability is shown in Annex F.

4.2.13 Test piece

(Addition:)

The test piece shall be cylindrical and opaque, with a minimum effective length of 150 mm. The diameter of the test piece shall not exceed the AOPD detection capability stated by the supplier.

For an AOPD detection capability of not more than 40 mm, the test piece for a light curtain shall be provided by the supplier and shall be marked with the following:

- diameter in millimetres;
- type reference and an indication of the AOPD with which the test piece is intended to be used.

When more than one detection capability can be configured on the AOPD, the supplier shall provide a test piece for each detection capability.

Verification shall be by inspection.

4.2.14 Wavelength

(Addition:)

AOPDs shall operate at a wavelength within the range 400 nm to 1 500 nm.

4.2.15 Radiation intensity

(Addition:)

The radiation intensity generated and emitted by the AOPD shall at no time exceed the maximum power or energy levels for a class 1M device in accordance with **8.2** of **JIS C 6802**.

NOTE : The use of class 2M devices is under consideration.

4.3 Environmental requirements

(Addition:)

4.3.5 Light interference

The ESPE shall continue in normal operation when subjected to

- incandescent light;
- flashing beacons;
- fluorescent light operated with high-frequency electronic power supply.

The ESPE shall not fail to danger when subjected to

- incandescent light (simulated daylight using a quartz lamp);
- stroboscopic light;
- fluorescent light operated with high-frequency electronic power supply;
- for a type 4 ESPE, radiation from an emitting element of identical design.

NOTE : Requirements for protection of type 2 ESPEs from radiation from an emitting element of identical design are under consideration.

These requirements shall be met when the ESPE conforms to the tests in **5.4.6**.

No requirements are given for immunity to other extraneous light sources which may cause abnormal operation or failure to danger. A requirement for the supplier to inform the user of potential problems is given in **af)** of clause **7**.

5 Testing

(This clause of Part 1 is applicable except as follows:)

5.1 General

(Addition:)

In the following tests, it shall be verified that when the OSSD(s) go to the OFF-state, they remain in the OFF-state while the test piece is present in the detection zone (or light beam) or for at least 80 ms, whichever is greater. If the AOPD incorporates a restart interlock, the restart interlock shall be disabled during the tests of this clause.

5.1.1 Type tests

5.1.1.2 Operating condition

(Addition:)

For the purpose of these tests, the plane of the light curtain detection zone may be either vertical or horizontal as preferred for a test.

If it can be demonstrated that the results will be the same, testing at long operating distances may be simulated by the use of neutral density (ND) filters.

NOTE : ND filters have an approximately-constant transmittance in a specific wavelength region and are used to reduce the light intensity without changing the spectral distribution.

5.1.2 Test conditions

5.1.2.2 Measurement accuracy

(Addition to first paragraph:)

- for angular measurement: $\pm 0.1^\circ$;
- for light intensity measurement: $\pm 10\%$.

5.2 Functional tests

5.2.1 Sensing function and detection capability

(Replacement:)

5.2.1.1 Sensing function

It shall be verified that the sensing device is continuously actuated and, where appropriate, that the OSSD(s) go to the OFF-state as described in this subclause, taking into account the operating principle of the AOPD and, in particular, the techniques used to provide tolerance to environmental interference.

For a light curtain:

- by slowly moving the test piece in the detection zone across the beams at an angle of 45° and at an angle of 90° (see figures 3 and 4) at each end of the detection zone [as near as practical to the emitter and receiver (or retro-reflector)] and midway between the ends (see figure 5);
- by placing the test piece in the detection zone, stationary, at any position and/or angle considered critical as a result of the analysis in 5.2.9.1;
- by moving the test piece in the detection zone, across the beams at the maximum speed in the range specified in 4.1.2.1 (0 m/s to 1.6 m/s), and at any other speed in that range which is considered critical as a result of the analysis in 5.2.9.1;

- by moving the test piece (having a length of 150 mm) through the detection zone at 1.6 m/s such that the direction of movement and the axis of the test piece are normal to the detection plane, at the extremities of the detection zone (for example, at each corner) and in any other position that is considered critical as a result of the analysis in **5.2.9.1**.

For a light beam device:

- by placing the test piece in the beam at each end of the beam and midway along the beam such that the axis of the test piece is normal to the axis of the beam;
- by moving the test piece (having a length of 150 mm) through the beam at 1.6 m/s such that the direction of movement and the axis of the test piece are normal to the axis of the beam, at each end of the beam midway along the beam, and at any point throughout the operating distance which is considered critical as a result of the analysis in **5.2.9.1**.

The above tests shall be performed with the AOPD operating at the minimum specified operating distance or 0.5 m, whichever is the greater, and at the maximum specified operating distance.

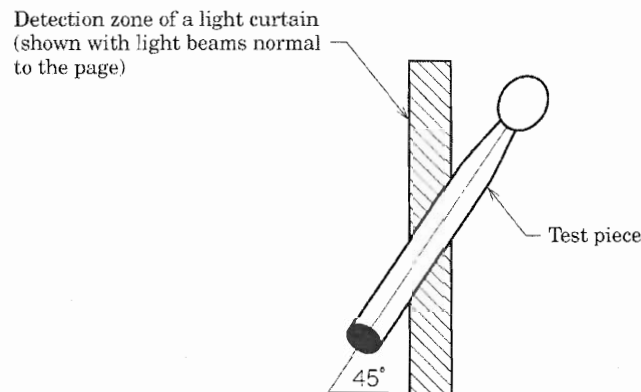


Figure 3 Test piece at 45°

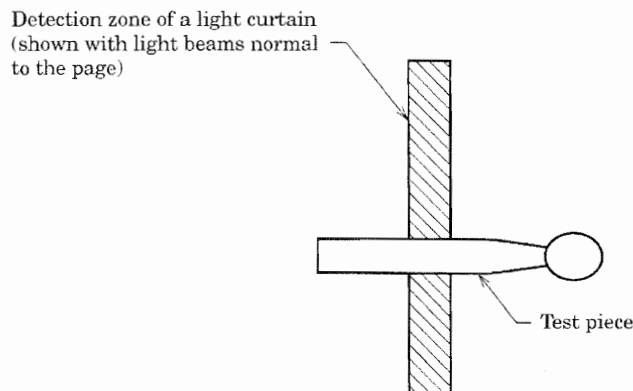


Figure 4 Test piece at 90°

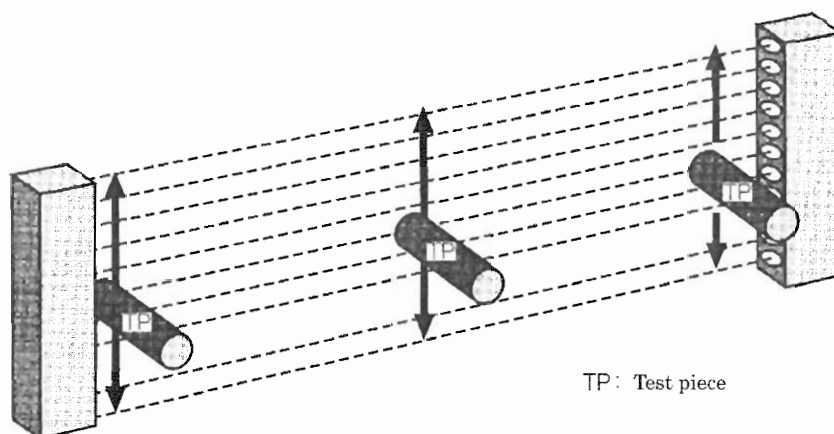


Figure 5 Verifying sensing function by moving the test piece (TP) through the detection zone near the emitter, near the receiver/retro-reflector target and at the midpoint

5.2.1.2 Integrity of the AOPD detection capability

It shall be verified that the AOPD detection capability is continuously maintained or the ESPE does not fail to danger, by systematic analysis of the design of the AOPD, using testing where appropriate, taking into account all combinations of the conditions specified in 4.1.2 and 4.2.12, and the faults specified in 5.3 (Part 1).

In cases where it is established that the AOPD detection capability is achieved by optical geometry based on the complete obscuration of at least one light beam anywhere within the detection zone (as shown in Annex F), further analysis and testing may not be necessary. In cases where detection capability is not achieved by complete obscuration, at least the following additional tests shall be carried out:

- align the AOPD in accordance with the suppliers specifications;
- place a ND filter with a transmittance of 30 % and with a dimension twice the size of the detection capability into the detection zone;
- switch AOPD on and wait for 30 s (or longer, if necessary, on the basis of the analysis of 5.2.9.1). Verify that the OSSD(s) are in the ON-state. If the OSSD(s) are in the OFF-state, the operating distance shall be reduced and the test restarted;
- insert the test piece in front of the ND filter. Verify that the OSSD(s) go to the OFF-state within the response time;
- remove the ND filter and verify that the OSSD(s) continuously remain in the OFF-state;
- repeat the test at several locations as determined by the analysis of 5.2.9.1.

The results of the systematic analysis shall identify which tests in 5.4 require, in addition, a measurement of the response time.

5.2.1.3 Additional tests for an AOPD using retro-reflective techniques

The following tests shall be conducted at both the minimum and maximum operating distance specified by the manufacture.

For a single light beam device, it shall be verified that the sensing device is actuated when a reflective object (as specified in **4.1.2.3**) of a size greater than, or equal to, the diameter and length of the test piece is placed on, and normal to, the optical axis of the light beam device. This test shall be conducted near the emitter/receiver, 200 mm in front of the retro-reflector target and midway along the beam.

For a light curtain and a multiple light beam device using retro-reflective techniques, it shall be verified that the OSSD(s) go to the OFF-state when a reflector identical to the retro-reflector target is placed in contact with the sensing surface of the emitting/receiving element(s).

For a light curtain it shall be verified that the sensing device is actuated when:

- a) highly reflective cylindrical object of a size greater than or equal to that of the test piece is placed within the detection zone of a light curtain, and
- b) a reflective object (as specified in **4.1.2.3**) is inserted within the detection zone of the light curtain.

These tests shall be conducted near the emitter/receiver, near the retro-reflector target and midway along the beam.

5.2.1.4 Additional tests for AOPDs using mixed emitter/receivers in the same assembly

It shall be verified that the sensing device is actuated when a reflective object (as specified in **4.1.2.4**) is inserted within the detection zone of the AOPD. The reflective object shall be placed near the emitter/receiver and midway within the detection zone.

5.2.9 Verification of optical performance

(Addition:)

5.2.9.1 Analysis of the electro-optical subsystem

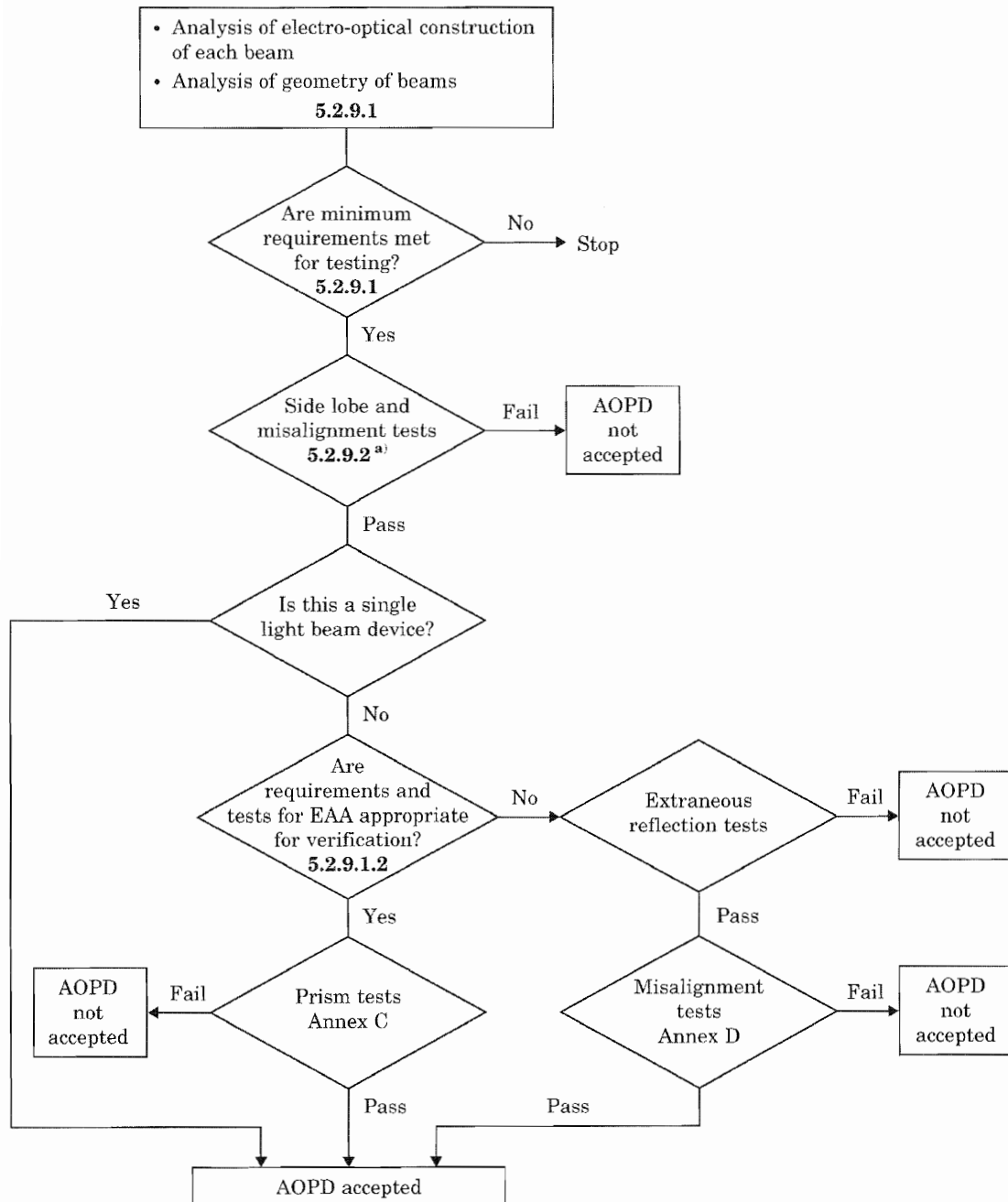
5.2.9.1.1 Analysis

A systematic analysis of the electro-optical subsystem shall be carried out to determine:

- a) the beam centre-line and the optical axes of the emitting and receiving elements;
- b) the relative intensity/sensitivity off-axis in all directions of the emitting and receiving elements;
- c) confirmation of any filtering techniques employed and their characteristics;
- d) the criteria used to determine the status of the sensing function;
- e) the relative intensity/sensitivity of the beams in the multibeam devices;
- f) the effect of undetected faults, in accordance with **4.2.2**, on the electro-optical characteristics;
- g) the worst-case response time;
- h) the effects of environmental influence, in accordance with **4.3** on the electro-optical characteristics.

The results of this analysis shall be used to determine if the requirements of **4.1.2.2** can be met.

If the requirements of **4.1.2.2** can be met, then the results of the analysis shall be used to determine which test method is appropriate for the verification (see figure 6).



Note ^{a)} The absence of side lobes is verified when the procedure in **5.2.9.2** is completed satisfactorily.

Figure 6 Analysis and tests of AOPDs—Flow chart

5.2.9.1.2 Selection of test method

Verification of the optical performance required by **4.1.2.2** can be performed using different methods depending on the design of the AOPD.

Factors that shall be taken into account in selecting the verification method are:

- intensity of the beam on and off the beam axis;
- sensitivity of the receiver on and off the beam axis;
- beam direction and orientation between similar elements (i.e. between one emitting arrangement and another, or between one receiving arrangement and another).

All AOPDs must pass the test for protection against side lobes and gross misalignment as described in **5.2.9.2**.

For AOPDs with more than one beam, it shall be verified that all beams meet the requirements. Two methods of verification are given in Annexes D and E of this Standard. Methods other than those described in Annexes D and E may be more appropriate depending of the design of the AOPD (and the analysis of **5.2.9.1.1**) and may be used if they can be shown to be equivalent.

NOTE: These methods may include, for example, the use of additional or substitute emitters or receivers.

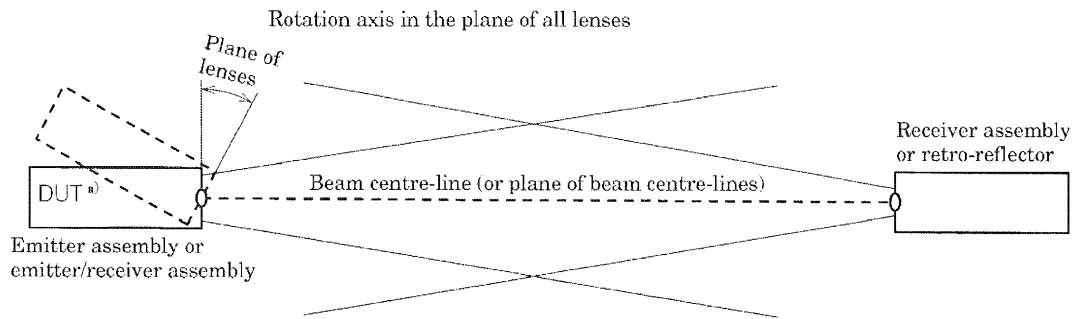
If meeting the requirements of **4.1.2.2** depends on controlling EAA, then it shall be shown that each beam in a multibeam device meets the requirements. One method of verifying the characteristics of each beam is with the use of a wedge prism placed in front of individual beams. The precision wedge prism offsets the EAA of the beam under test so that its individual characteristics can be evaluated. The wedge prism test procedure is explained in Annex D. Passing the wedge prism test satisfies items **a)** and **b)** of **4.1.2.2**.

When other techniques (alternative to the restriction of the EAA) are used to meet the requirements of **4.1.2.2**, the optical performance of the AOPD can be measured directly by using a mirror test and an alignment test. In the mirror test, a small mirror is placed near each beam to evaluate its individual characteristics. These test procedures are explained in Annex E. Passing the tests of Annex E satisfies items **a)** and **b)** of **4.1.2.2**.

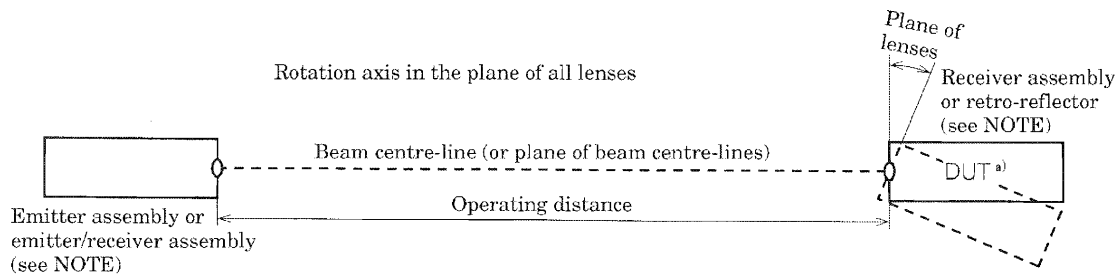
5.2.9.2 Side lobe and misalignment test (measurement of EAA)

With an emitter assembly or an emitter/receiver assembly, fixed in optical alignment with a receiver assembly or a retro-reflector target, the angle of misalignment (EAA) of the receiver assembly or the retro-reflector target shall be measured [see figure 7, 2)]. With a receiver assembly or retro-reflector target fixed in optical alignment with an emitter assembly or an emitter/receiver assembly, the angle of misalignment (EAA) of the emitting element or the emitter/receiver element shall be measured [see figure 7, 1)]. These measurements shall be carried out at all the distances indicated in figure 2 in the following manner.

The AOPD shall be optimally aligned as specified by the supplier. The AOPD should be mounted on a turn table with an angle scale. The tests shall be performed about the rotational axis indicated in figure 7.



1) Rotation of the emitter assembly with the receiver assembly fixed



2) Rotation of the receiver assembly with the emitter assembly fixed

NOTE : For light curtains employing retro-reflective techniques, the test should only be carried out on the sensing unit with the retro-reflector target fixed.

Note ^{a)} DUT: device under test

Figure 7 Measuring method for EAA (direction)

Switch the AOPD on and carry out the procedure as follows:

- a) the emitter or emitter/receiver unit shall be turned clockwise into the 90° position; the OSSD(s) shall go to the OFF-state;
- b) the supply voltages of the complete AOPD shall be switched off and then on again;

NOTE 1 Based on the analysis of 5.2.9.1, it may be necessary to wait for some time (for example, settling time of gain control circuits) between the steps of this procedure and between steps **b)** and **c)**.

- c) the emitter or emitter/receiver unit shall be turned back towards the aligned position until the position is reached at which the OSSD(s) go to the ON-state. This value of the angle and distance shall be recorded. Continue turning the unit in the counter-clockwise direction until the opposite 90° position is reached and record the last position at which the OSSD(s) change from the ON-state to the OFF-state;
- d) the same procedure given in steps **a)** to **c)** shall be performed in the counter clockwise direction;
- e) the same procedure given in steps **a)** to **d)** shall be applied to the opposite unit (receiver or receiver/emitter).

In cases where the minimum operating distance specified exceeds 3 m, similar tests shall be performed to determine the EAA at the minimum operating distance (see figure 2).

The test is passed when the angles recorded in step **c**) (EAA) are less than the values indicated in figure 2.

NOTE 2 For an AOPD specified by the manufacturer to operate over long distances, tests may be carried out using ND filters over shorter distances, when it can be shown that the results obtained will correspond with those results obtained at the specified operating distance.

NOTE 3 Particular attention should be given to designs where the cross-section of the beam (for an emitter) or the cross-section of the cone of reception (for a receiver) is designed to be oval, elliptical, oblong or otherwise elongated in a direction which is neither horizontal nor vertical.

5.2.10 Wavelength

(Addition:)

The transmitted wavelength shall be verified either by inspection of the device data sheets or by measurement.

5.2.11 Radiation intensity

(Addition:)

The radiation intensity shall be verified by measurement in accordance with **JIS C 6802** and inspection of the technical documentation provided by the supplier.

NOTE : Simplified testing methods for verification of this requirement are being developed.

5.4 Environmental tests

(Addition:)

5.4.6 Light interference

5.4.6.1 General

Each test shall be carried out at an operating distance of 3 m (or the closest normal operating distance to 3 m as specified by the supplier) and under the stated conditions as a minimum requirement³⁾.

Note ³⁾ Subclauses **5.4.6.2** to **5.4.6.8** constitute a part of minimum requirement.

Additional tests shall be carried out under different combinations of operating distances and environmental conditions when:

- the supplier states higher immunity levels, which shall be verified by testing at those levels with appropriate light sources; and/or
- the analysis of **5.2.1.2** or **5.2.9.1** shows such tests to be necessary.

During B tests and C tests, the test piece shall be introduced into the detection zone in such a manner that the interfering light is not interrupted.

For the tests in **5.4.6.4**, the system shall be optimally aligned in accordance with the manufacturer's instructions. The tests in **5.4.6.5**, **5.4.6.6** and **5.4.6.7** require that the interfering light be directed along the optical axis (or as close as practical) of a

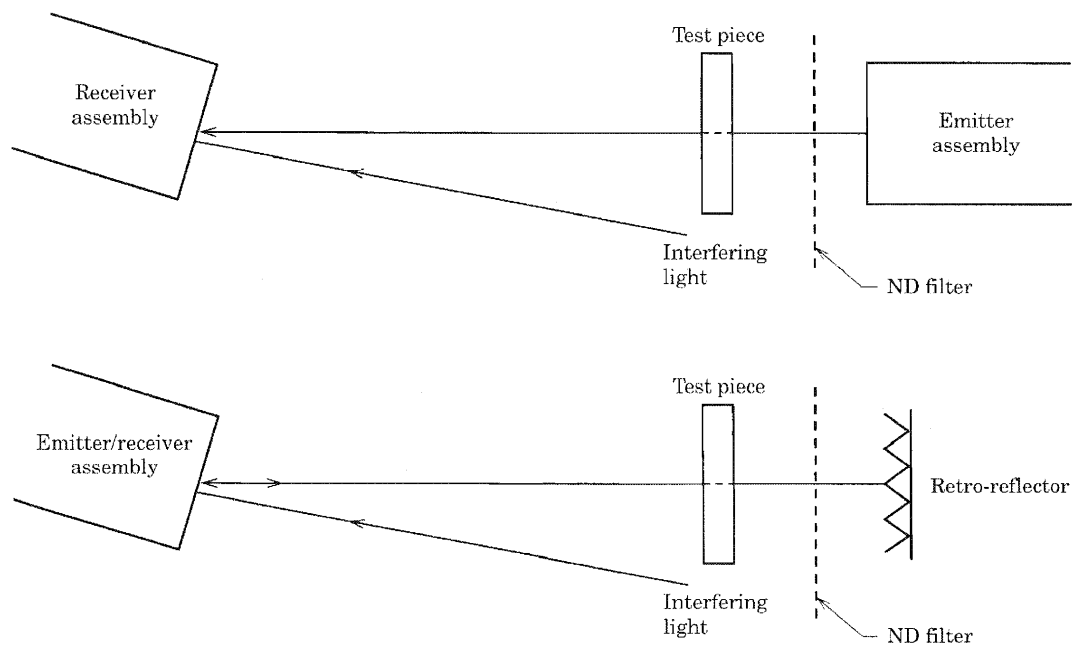
receiving element(s) and with the emitting element(s) at maximum angular misalignment at which normal operation continues (worst-case alignment). The test arrangement used shall be compatible with the characteristics of the AOPD under test, as determined by the analysis and tests of **5.2.9.1** and **5.2.9.2**, and any further analysis and characterization which proves to be necessary (see figures 8, 9, 10, 11 and 12 for examples).

NOTE 1 As a result of the diversity of designs, no single test arrangement is suitable for all types of AOPD. An example of a test configuration is illustrated in figure 8.

NOTE 2 During the tests, long-range operation may be simulated by ND filters, as illustrated in figure 8, providing that results are not affected.

NOTE 3 If a ND filter is used, then all tests should be performed after the ND filter is installed.

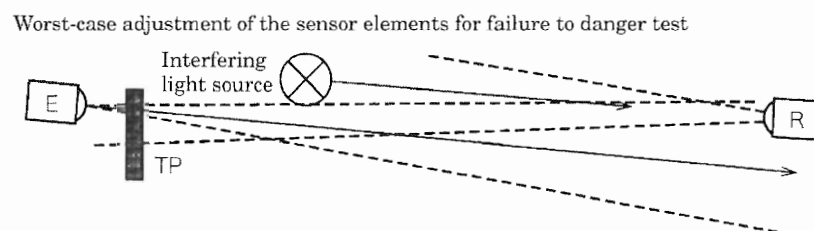
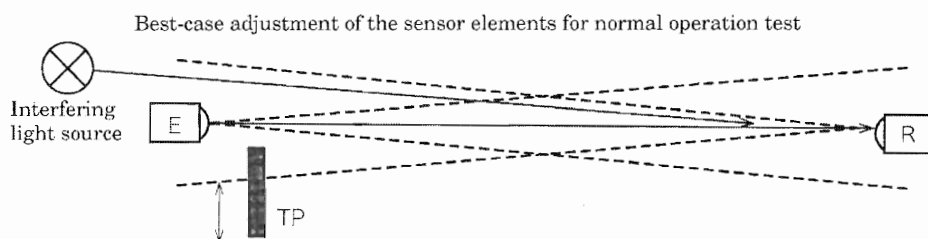
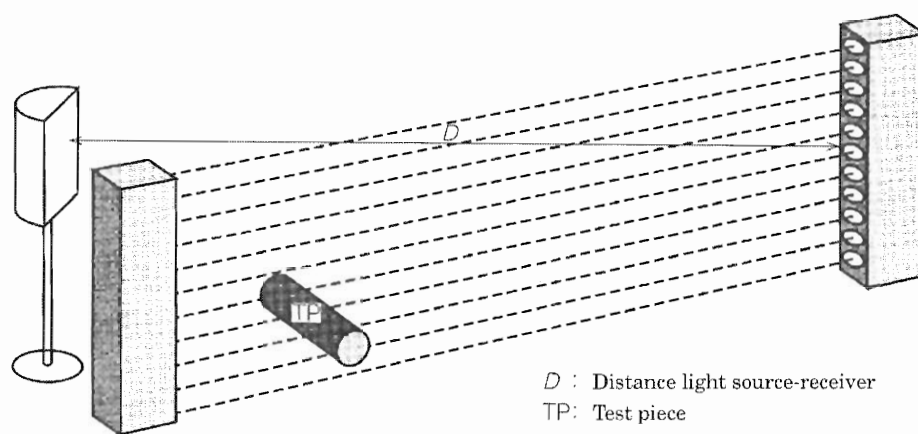
The test arrangement shall not modify the characteristics of the light reaching the receiving elements of the AOPD in any way that affects the operation of the AOPD. Where reflectors, mirrors, filters, beam splitters, windows, etc. are employed, it shall be verified that any alteration of the characteristics of the light (for example spectral distribution or polarization) is without significant effect.



NOTE 1 Receiver or emitter/receiver assemblies are operated at maximum possible misalignment for fail to danger tests.

NOTE 2 ND filters may affect polarization.

Figure 8 Light interference test (Direct method)

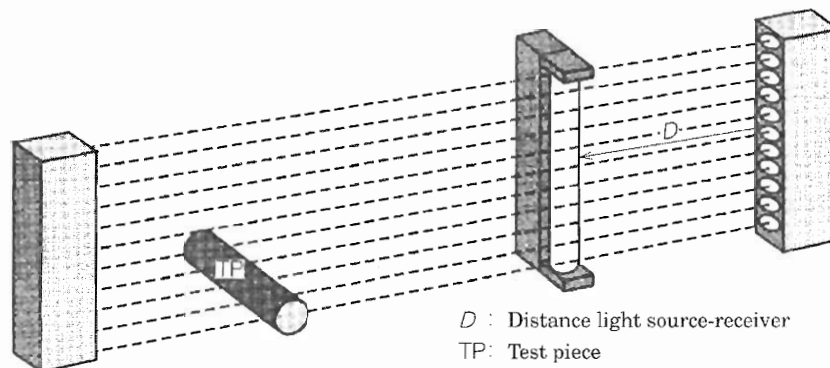


The distance between emitter and receiver is 3 m.

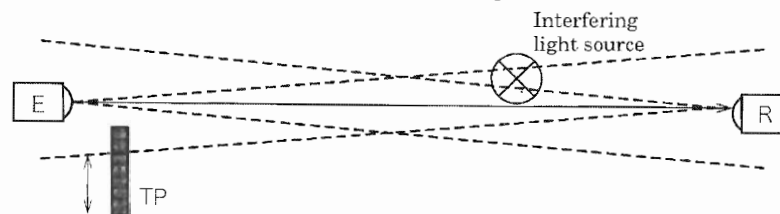
For the distance D between receiver and light source, see the table below.

| Distance D (The exact distances depend on the lamp type.) | Illuminance | NOTE |
|--|-------------|-------------------------------------|
| 2 m | 3 000 lx | Distance for fail to danger test. |
| 3 m | 1 500 lx | Distance for normal operation test. |

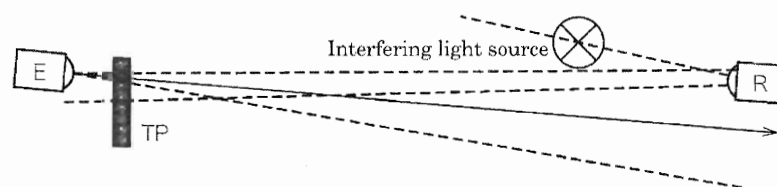
Figure 9 Light interference test (Test set-up with halogen light source)



Best-case adjustment of the sensor elements for normal operation test



Worst-case adjustment of the sensor elements for failure to danger test

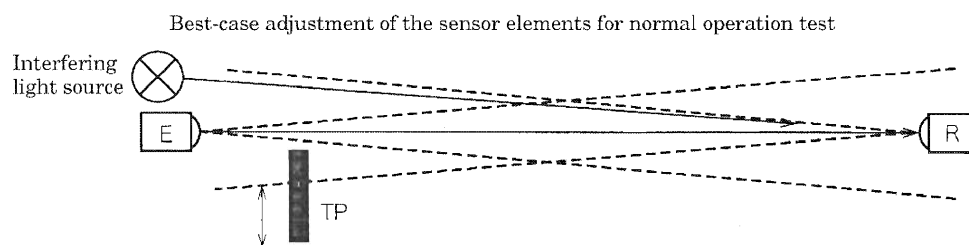
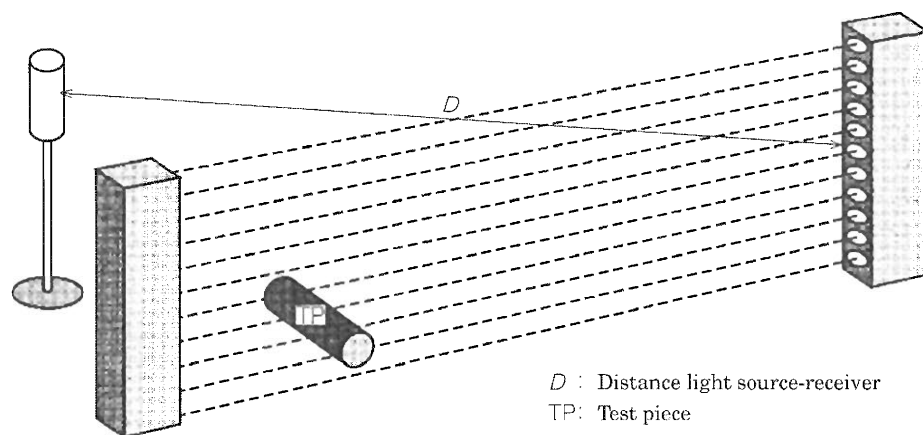


The distance between emitter and receiver is 3 m.

For the distance D between receiver and light source, see the table below.

| Distance D (The exact distances depend on the lamp type.) | Illuminance | NOTE |
|--|-------------|-------------------------------------|
| 12 cm | 3 000 lx | Distance for fail to danger test. |
| 21 cm | 1 500 lx | Distance for normal operation test. |

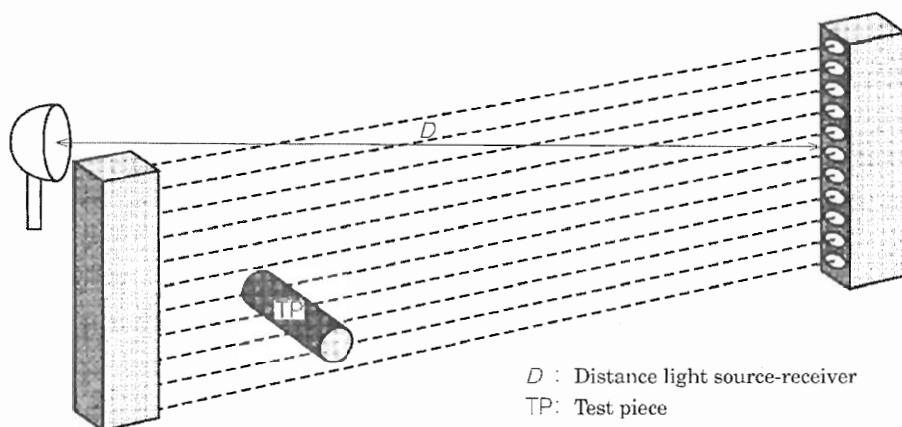
Figure 10 Light interference test (Test set-up with fluorescent light source)



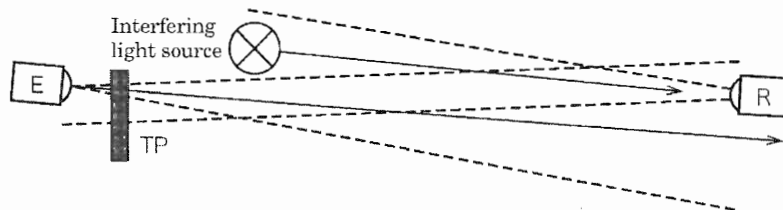
The distance between emitter and receiver is 3 m.

The distance D between receiver and light source is 3 m.

Figure 11 Light interference test (Test set-up with xenon flashing beacon)



Worst-case adjustment of the sensor elements for failure to danger test



The distance between emitter and receiver is 3 m.

The distance D between receiver and light source is 1 m (for fail to danger test).

Figure 12 Light interference test (Test set-up with strobe lamp)

5.4.6.2 Light sources

The light sources shall be as follows.

- a) **Incandescent light source:** a linear tungsten halogen (quartz) lamp with the following characteristics:
 - colour temperature: 3 000 K to 3 200 K;
 - input power: 0.5 kW to 1 kW rated power;
 - rated voltage: any value within the range 100 V to 250 V;
 - supply voltage: rated voltage $\pm 5\%$, sinusoidal a.c. at 48 Hz to 62 Hz;
 - length: 150 mm to 250 mm nominal.

The lamp shall be mounted in a parabolic reflector of minimum dimensions 200 mm \times 150 mm, having a diffuse finish and a uniform reflectance within $\pm 5\%$ over the wavelength range 400 nm to 1 500 nm.

NOTE : A lamp with a diffuse finished front window is also acceptable. This source produces a beam of near uniform intensity with known spectral distribution and having a predictable modulation at twice the supply frequency. It is used to simulate both sunlight and workplace incandescent lighting.

- b) **Fluorescent light source:** a linear fluorescent tube with the following characteristics:

- size: T8 × 1 200 mm (25 mm nominal diameter);
- rated power: 18 W to 20 W;
- colour temperature: 5 000 K to 6 000 K, used in combination with an electronic ballast having the following characteristics:
- operating frequency: 30 kHz to 40 kHz;
- power rating corresponding to the tube and operated at its rated supply voltage $\pm 5\%$, without a reflector or diffuser.

- c) **Flashing beacon light source:** a light source employing a xenon flash tube (without enclosure, reflector or filter) having the following characteristics:

- flash duration: from 40 μs to 1 200 μs (measured to the half-intensity point);
- flash frequency: 0.5 Hz to 2 Hz;
- input energy per flash: 3 J to 5 J.

- d) **Stroboscopic light source:** a stroboscope employing a xenon flash tube (without enclosure, reflector or filter) having the following characteristics:

- flash duration: from 5 μs to 30 μs (measured to the half-intensity point);
- flash frequency: 5 Hz to 200 Hz (adjustable range);
- input energy per flash: 0.05 J (at 200 Hz) to 0.5 J (at 5 Hz).

The position of the flash tube shall be fixed during the test.

5.4.6.3 Test sequences

NOTE : The B and C tests below are defined in Part 1, 5.2.3.

Test sequence 1:

- 1) ESPE in normal operation
- 2) Switch on interfering light
- 3) B test
- 4) Switch off ESPE for 5 s. Restore power. Reset start interlock, if fitted
- 5) B test
- 6) Switch off interfering light
- 7) B test

Test sequence 2:

- 1) ESPE in normal operation
- 2) Switch on interfering light
- 3) C tests repetitively for 1 min

- 4) Switch off ESPE for 5 s. Restore power. Reset start interlock, if fitted
- 5) C tests repetitively for 1 min
- 6) Switch off interfering light
- 7) C tests repetitively for 1 min

Test sequence 3:

- 1) ESPE in normal operation
- 2) Switch on the interfering light
- 3) C tests repetitively for 3 min

5.4.6.4 Normal operation (best alignment)

The ESPE shall continue in normal operation throughout test sequence 1 in **5.4.6.3** using each of the following types of interfering light, directed along the optical axis of one or more receiving elements:

- the incandescent light source of **5.4.6.2** producing a light intensity of 1 500 lx measured at the plane of the receiving element(s) (figure 9);
- the flashing beacon light source of **5.4.6.2** shall be placed at distance of 3 m within EAA of the receiving element(s) for 1 min (figure 11);
- the fluorescent light source of **5.4.6.2** producing an intensity of 1 500 lx at the plane of the receiving element(s) (figure 10). This test shall be performed with three variations, using light from the centre and light from each end (anode and cathode areas) of the tube.

NOTE : One objective of the test using the fluorescent light source is to check the susceptibility of the AOPD to high-frequency modulated optical radiation.

5.4.6.5 Failure to danger—Incandescent light (3 000 lx and worst-case alignment)

There shall be no failure to danger during test sequence 2 of **5.4.6.3** using the incandescent light source of **5.4.6.2** directed along the optical axis of one or more receiving elements, producing a light intensity of 3 000 lx \pm 300 lx, measured at the plane of the receiving elements (figure 9).

5.4.6.6 Failure to danger—Stroboscopic light (worst-case alignment)

There shall be no failure to danger during test sequence 3 of **5.4.6.3** using the stroboscopic light source of **5.4.6.2** directed along the optical axis of one or more receiving elements (figure 12). The flash rate of the source shall be increased linearly from 5 Hz to 200 Hz over a period of 3 min, during which time the C test shall be continuously repeated.

5.4.6.7 Failure to danger—Fluorescent light (3 000 lx and worst-case alignment)

There shall be no failure to danger with the radiation of the fluorescent light source of **5.4.6.2** producing an intensity of 3 000 lx at the plane of the receiving element(s) (figure 10). This test shall be performed with three variations, using light from the

centre and light from each end (anode and cathode areas) of the tube. Test sequence 2 of **5.4.6.3** shall be used.

5.4.6.8 Failure to danger—Interfering light from an emitting element of identical design

There shall be no failure to danger of a type 4 ESPE when the radiation from the emitting elements of an AOPD of identical design is directed towards the receiving elements of the AOPD under test, either directly or via the retro-reflector target if used. A minimum of six positions shall be selected, representative of worst-case conditions as determined by the analysis of **5.2.1.2** and **5.2.9.1**. The AOPD shall operate at the maximum working distance specified by the supplier. Test sequence 3 of **5.4.6.3** shall be used. Either the test piece shall be detected or the OSSD(s) shall go to the OFF-state. Where different codes, sizes and configurations are possible an analysis shall be made. The most critical combinations shall be tested against failure to danger.

6 Marking for identification and safe use

(This clause of Part 1 is applicable except as follows:)

6.1 General

(Addition:)

Add to **b)**:

- When separate parts of the AOPD have different detection capabilities, those parts and their detection capabilities shall be marked on the outside of the AOPD. When that is not practicable (for example, due to lack of space), the information shall be included in the accompanying documents.
- The minimum and maximum operating distances shall be marked.
- Should the OSSD be able to go to the ON-state when the receiving elements and the emitting elements are incorrectly mounted, i.e. 180° misalignment, the AOPD shall be marked so that the correct mounting position relative to each other is clearly identified.
- For light curtains, the limits of the detection zone shall be clearly marked.
- Marking shall be provided to indicate the beam centre-line(s).

NOTE : The beam centre-line(s) is one of the factors used to determine the position of the AOPD.

7 Accompanying documents

(This clause of Part 1 is applicable except as follows:)

(Additions:)

[Add to **f)**:]

When different parts of the AOPD have different detection capabilities, the size of the test piece for each different part together with the different detection capabilities shall be given together with the corresponding procedure for checking

the detection capabilities and the operation of the visual indicator(s). Information about the size of an object that will never be detected should also be provided.

[Add to *i*):]

The details of any precautions to be taken when installing the AOPD shall be given, including the EAA(s) of the specified device(s), together with any other relevant installation drawings giving details on how the AOPD detection capability may be affected by any reflective surfaces on or near the machine or on the material being worked.

[Add to *v*):]

Details of the penetration of the test piece into the detection zone that is necessary to ensure actuation of the sensing device, for all possible directions of approach, in relation to an identifiable datum on the AOPD [for example beam centre-line(s)] shall be given.

The maximum speed of movement of the test piece, or equivalent up to which the detection capability is maintained, shall be given.

When the AOPD is provided with means for adjustment of the spatial position of the light curtain, the range of adjustments and the corresponding position of the detection zone shall be shown in diagrammatic form in the accompanying documents. For a light curtain, clearly legible drawings shall be provided to ensure that emitting elements and receiving elements are correctly mounted with respect to each other, particularly to avoid 180° misalignment.

[Add to *af*):]

A statement similar to the following shall be included: "Additional measures may be necessary to ensure that the ESPE does not fail to danger when other forms of light radiation are present in a particular application (for example, use of cableless control devices on cranes, radiation from weld spatter or effects from stroboscopic lights)."

(Add:)

- am) Information on how to calculate the minimum distances in accordance with **JIS B 9715** when blanking is implemented. Explain that when blanking is used, the minimum distance should always relate to the minimum (worst-case) object detection capability (The minimum distance different from that in the case without blanking may well be necessary).
- an) Information can be found in **TS B 62046** describing additional means that may be required to prevent a person from reaching into the hazard through the blanked areas of the detection zone.
- ao) Recommendation that a responsible person verifies the detection zone using an appropriate test piece after its configuration.

Annex A (normative)

Optional functions of the ESPE

Introduction

This Annex specifies optional functions of the ESPE.

Requirement

Annex A of Part 1 applies except as follows.

(Addition:)

A.9 Blanking

Functional requirements

Detection capability and the part of the detection zone to which blanking is applied shall meet the same fault detection requirements as all other safety-relevant functions of the AOPD.

AOPDs may provide a feature which monitors the continued interruption of the blanked beams (monitored blanking). AOPDs provided with blanking functions shall satisfactorily pass all the light interference tests of **5.4.6** with the blanking functions enabled. These requirements shall apply to all modes of blanking. Indication should be provided to show when blanking is in operation.

NOTE : Additional requirements for blanking are under consideration.

Annex B (normative)
Catalogue of single faults affecting
the electrical equipment of the ESPE,
to be applied as specified in 5.3

Introduction

This Annex specifies single faults affecting the electrical equipment of the ESPE, to be applied as specified in **5.3**.

Requirement

Annex B of Part 1 is applicable.

Annex D (normative)

Verifying effective aperture angle (EAA) using the prism method

Introduction

This Annex specifies the method for verifying EAA using the prism.

D.1 General

This test shall be applied to multiple light beam devices and light curtain systems. The basis of this method is to isolate each beam so that its individual characteristics can be verified (figure D.1).

NOTE 1 For systems with different EAAs on the emitter and receiver, this procedure can be used as a guide to develop equivalent tests. However, different EAA limits need to be determined as appropriate for the design of the system being evaluated.

The AOPD shall be optimally aligned (zero position) and should be mounted on a turntable unit. A wedge prism with a beam deviation angle in accordance with MP1 of figure 2 shall be used for testing. The height (H , figure D.2) shall be large enough to cover at least one beam but shall not be more than the dimension of the detection capability. The test in **D.2** (referring to figure D.2) shall be made at 3 m, or as close to 3 m as possible within the working range of the device (when the test is made at a distance other than 3 m, the formulas of figure 2 shall be used to calculate an appropriate deviation angle).

NOTE 2 Based on the analysis of **5.2.9.1**, tests at other distances may be necessary.

The prism angle β can be calculated with the formulae shown in figure D.3.

D.2 Prism test procedure

Switch the AOPD on and carry out the following procedure.

- 1) The OSSD(s) shall be in the ON-state.
- 2) Insert the prism centred in front of the receiving or emitting element to be tested.
- 3) The OSSD(s) shall change to, and remain in, the OFF-state. If the OSSD(s) remain in the ON-state, rotate the turntable in the direction of the beam deviation until the OSSD(s) change(s) to the OFF-state. Remove the prism and verify that the OSSD(s) return to ON-state.
- 4) Turn the prism 180° and insert the prism in front of the same beam to be tested. Verify that the OSSD(s) change(s) to, and remains in, the OFF-state. If the OSSD(s) remains in the ON-state, rotate the turntable in the direction of the beam deviation until the OSSD(s) change(s) to the OFF-state. Remove the prism and verify that the OSSD(s) return to the ON-state.
- 5) Repeat steps **3**) and **4**), inserting the prism from opposite directions, until the OSSD(s) change(s) to the OFF-state as required without changing the position of

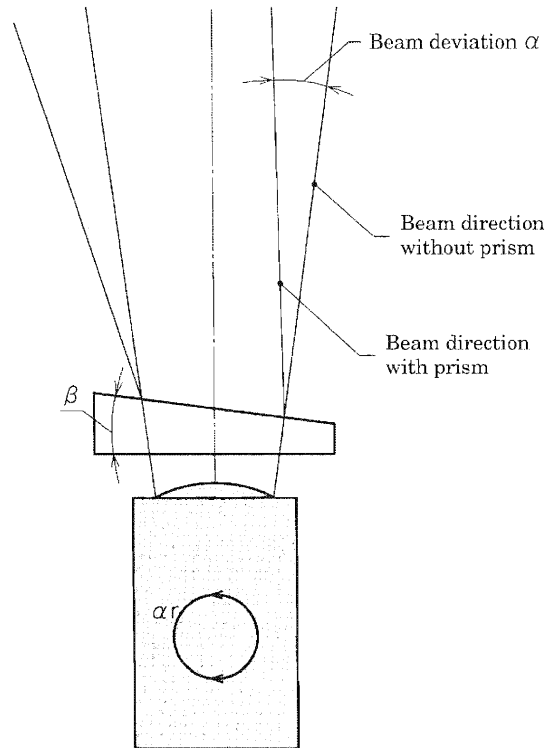
the turntable. If such a position cannot be found, then the EAA of the beam being tested exceeds the required angle.

NOTE : The purpose of the above sequence of tests is to find a single position of the turntable where the OSSD(s) can be made to change to the OFF-state by inserting the prism from either direction. This will verify that the EAA is the same in both directions.

- 6) Bring the turntable to the zero position and then repeat steps 1) to 5) for each beam. While repositioning the prism, the OSSD(s) are allowed to change state.

The test procedure described shall be repeated on at least the first and last beam with the system under test rotate 90° and the prism inserted along the Y axis (see figure D.2). The test shall be repeated for other positions if the analysis in accordance to 5.2.9.1 indicates that the other positions are critical.

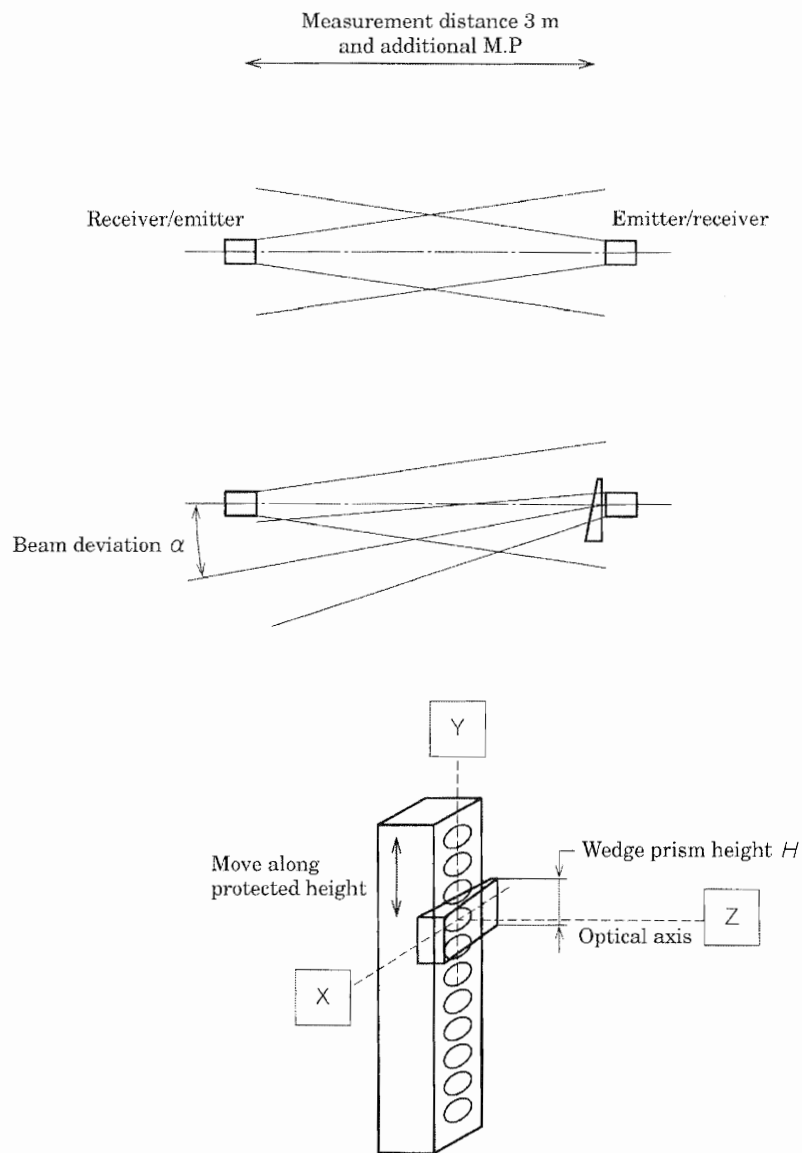
The above test shall be carried out both in front of the emitter and in front of the receiver.



NOTE 1 The prism should be located as close as possible in front of the optic.

NOTE 2 To achieve very large deviation angles, it may be necessary to use a combination of prisms.

Figure D.1 Prism test to measure EAA of each beam



For analysing an individual beam, H should completely cover only the beam being tested.

Figure D.2 EAA test using prism

The wedge prism deviation angle depends on the mechanical angle of the prism used, the refraction number for the kind of glass used and on the wavelength of the light.

The angle can be calculated using the following relation:

$$\beta = \frac{\alpha}{(n - 1)}$$

where β : the prism angle;
 α : the deviation angle;
 n : the refraction number.

Using a refraction number for the glass of 1.51 for 880 nm wavelength, the calculation for a deviation angle of 2.5° is:

$$\begin{aligned}\beta &= \frac{2.5}{(1.51 - 1)} \\ &= 4.9^\circ\end{aligned}$$

Deviation angles for different wavelengths and constant β (4.9°):

| Wavelength | Refraction n | $\alpha = \beta (n - 1)$ |
|------------|-------------------|-----------------------------|
| 440 nm | 1.5 | $4.9(1.5 - 1) = 2.45^\circ$ |
| 880 nm | 1.51 | $4.9(1.51 - 1) = 2.5^\circ$ |
| 1 500 nm | 1.53 | $4.9(1.53 - 1) = 2.6^\circ$ |

NOTE : Measuring error caused by differing wavelengths for 400 nm, it is -0.05° and for 1 500 nm, it is +0.1°.

Figure D.3 Design calculations for a wedge prism

Annex E (normative)

Verifying optical performance using the mirror method and misalignment test

Introduction

This Annex specifies the method for verifying optical performance using the mirror method and misalignment test.

E.1 Protection against improper alignment and extraneous reflections

When an AOPD does not use the method of limiting the EAA to meet the optical performance requirements of 4.1.2.2 and taking into account the results of the analysis of 5.2.9.1, fulfilment of the requirements of 4.1.2.2 to 4.1.2.4 shall be verified by a combination of analysis of the design and by acceptable performance of the tests in this Annex.

Since not all design techniques can be anticipated, these test procedures may not be suitable for a particular design technique and may require modification.

E.2 Verification of OFF-state when misaligned

It shall be verified that the OSSD(s) remain(s) in the OFF-state for misalignments (see figure E.1) that are in excess of the angles shown in tables E.1 and E.2, or as calculated with the formulas of figure E.1.

Table E.1 Maximum permissible angle of misalignment (γ) for a type 2 ESPE depending on the dimensions of the light curtain

Unit: °

| Operating range of the light curtain (longitudinal dimension) m | Distance between beam centre-lines of outermost beams (lateral dimension) mm | | | | | | | | | |
|--|---|------|------|------|------|-------|-------|-------|-------|-------|
| | 300 | 450 | 600 | 750 | 900 | 1 050 | 1 200 | 1 350 | 1 500 | 1 800 |
| Up to 3.0 | 51.8 | 33.8 | 25.2 | 20.1 | 16.7 | 141.3 | 12.5 | 11.1 | 10.0 | 8.3 |
| 4.0 | 71.4 | 45.8 | 33.9 | 27.0 | 22.4 | 19.2 | 16.8 | 14.9 | 13.4 | 11.2 |
| 5.0 | 93.6 | 58.2 | 42.8 | 33.9 | 28.1 | 24.4 | 21.0 | 18.6 | 16.8 | 14.0 |
| 6.0 | 122.1 | 71.4 | 51.9 | 41.0 | 33.9 | 29.0 | 25.3 | 22.4 | 20.2 | 16.8 |

Table E.2 Maximum permissible angle of misalignment (γ) for a type 4 ESPE depending on the dimensions of the light curtain

Unit: °

| Operating range of the light curtain (longitudinal dimension) m | Distance between beam centre-lines of outermost beams (lateral dimension) mm | | | | | | | | | |
|--|---|------|------|------|------|-------|-------|-------|-------|-------|
| | 300 | 450 | 600 | 750 | 900 | 1 050 | 1 200 | 1 350 | 1 500 | 1 800 |
| Up to 3.0 | 25.2 | 16.7 | 12.5 | 10.0 | 8.3 | 7.2 | 6.3 | 5.6 | 5.0 | 4.2 |
| 4.0 | 33.8 | 22.4 | 16.7 | 13.4 | 11.1 | 9.5 | 8.3 | 7.4 | 6.7 | 5.6 |
| 5.0 | 42.7 | 28.1 | 21.0 | 16.7 | 13.9 | 11.9 | 10.4 | 9.3 | 8.3 | 7.0 |
| 6.0 | 51.8 | 33.8 | 25.2 | 20.1 | 16.7 | 14.3 | 12.5 | 11.1 | 10.0 | 8.3 |

E.2.1 Misalignment test procedure

The AOPD shall be optically aligned in accordance with the supplier's instructions and the OSSDs shall be in the ON-state.

As shown in figure E.1, the angle of misalignment shall be increased from 0° to the angle at which the OSSD(s) go(es) to and remain in the OFF-state. That shall occur at an angle not exceeding that given in table E.1 or table E.2, as appropriate. The angle shall then be slowly increased to 180° during which time the OSSD(s) shall remain in the OFF-state. Where γ (see figure E.1) is greater than 160°, this test need not be carried out.

NOTE : As a result of the analysis of 5.2.9.1, modifications to the above procedure, or additional testing can be required (for example, to allow for automatic gain control).

E.3 Verification of protection against extraneous reflections

With the AOPD aligned in worst-case alignment conditions, it shall be verified that the AOPD will not fail to danger when a reflective surface(s) is placed nearby. This shall apply for each beam, under all other conditions within the supplier's specification.

E.3.1 Test procedure for effects of extraneous reflections

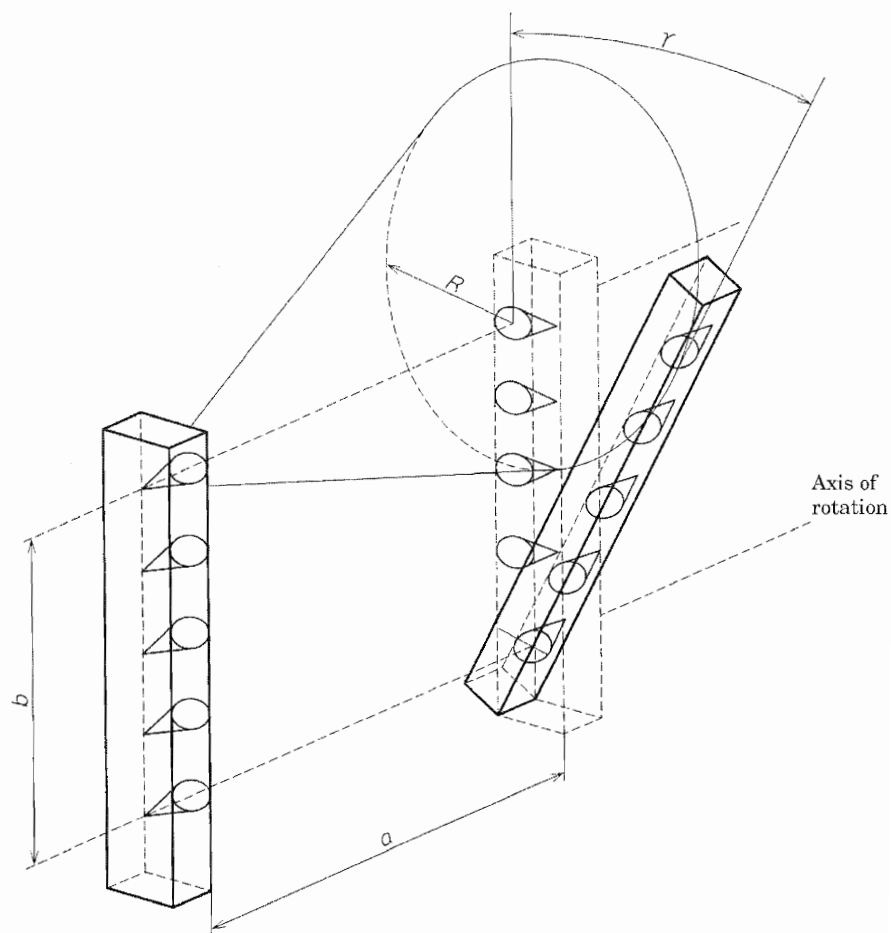
This test shall be carried out at each of the operating distances (0.5 m, 0.75 m, 1.5 m and 3.0 m) that are within the operation distance specified by the supplier. Where the minimum specified operating distance exceeds 3.0 m, the test shall be carried out at the minimum operating distance. The test shall be repeated for each beam centre-line.

After positioning the AOPD in the worst-case alignment position, power to the unit under test shall be switched off and then on again.

NOTE : Before beginning the test, it may be necessary to wait some period of time (for example, settling time of gain control circuits) after switching power on.

With a mirror placed at any position along the beam centre-line (at an appropriate distance as indicated in figure E.2) and inclined to achieve the maximum transmission of light from the emitter to the receiver, a C test shall be carried out with the test piece at the midpoint along the beam centre-line. The mirror shall have a flat surface of at least 200 mm by 200 mm, having a minimum reflectance of 0.9 at the emitted wavelength.

When C tests are performed, the direct light path between the emitter and the receiver shall be fully obstructed by the test piece, but the indirect light path via the mirror shall not have any part of its cross-section obstructed.



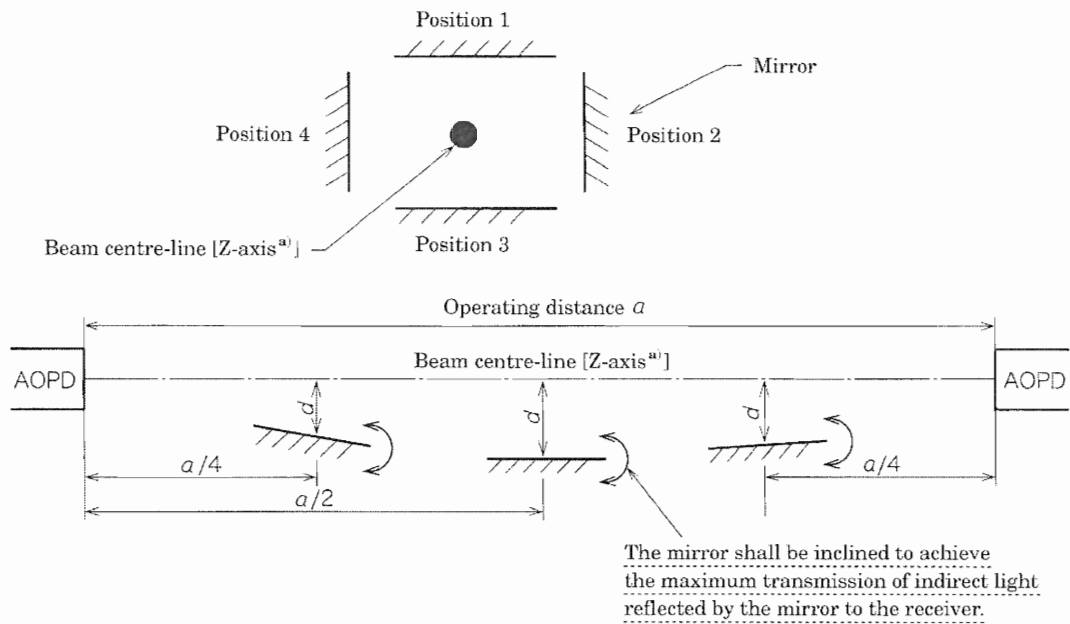
- a Operating range
 b Distance between beam centre-lines of outermost beams
 R Light spot radius
 γ Angle of rotation in degrees

$$\gamma = 2 \arcsin (R/2b)$$

Type 2 AOPD: $a \leq 3$ m $R = 260$ mm
 $a > 3$ m $R = a \tan 5.0^\circ$

Type 4 AOPD: $a \leq 3$ m $R = 130$ mm
 $a > 3$ m $R = a \tan 2.5^\circ$

Figure E.1 AOPD misalignment test



Tests requiring mirror positions within the detection zone are excluded.
Note ^{a)} See figure D.2 as for the direction of Z-axis.

Table of mirror positions

| Operating distance a m | Type 2 ESPE | Type 4 ESPE |
|--------------------------------|------------------|--------------------|
| | D mm | d mm |
| 0.5 to 3.0 | 262 | 131 |
| $a > 3.0$ | $a \tan 5^\circ$ | $a \tan 2.5^\circ$ |

Figure E.2 Extraneous reflections test

Annex F (informative)

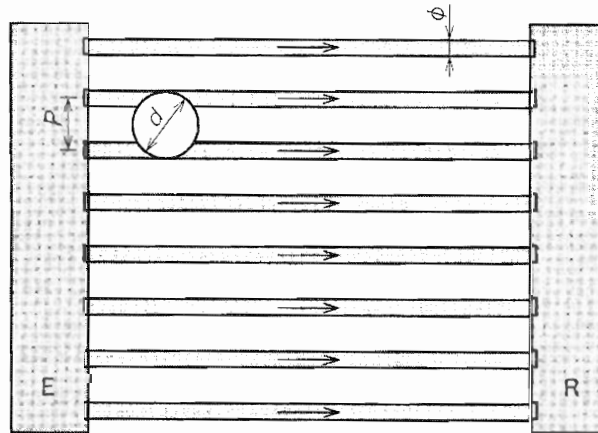
AOPD detection capability based on complete obscuration

Introduction

This Annex is to describe AOPD detection capability based on complete obstruction and not to constitute the provisions of this Standard. The method for determining AOPD detection capability based on the physical characteristics of a light curtain is stated here, but nothing stated here shall be construed to require use of this method.

F.1 Method for determining detection capability

For a light curtain, the value of detection capability stated by the supplier can be based on the complete obscuration of at least one beam for any and all positions of the test piece within the detection zone.



The formula ($d = P + \phi$) is used for determining minimum detection capability (d) based on the physical characteristics of a light curtain design.

Example: lens diameter (ϕ) = 6 mm

beam spacing (P) = 8 mm

$$d = P + \phi = 8 \text{ mm} + 6 \text{ mm} = 14 \text{ mm}$$

Therefore, in the above example, detection capability = 14 mm.

NOTE : A calculation based on the above example requires that the spacing between beam centre-lines is uniform and the diameter of the optical element is the same on both the emitter and receiver. Where diameters are different, the largest diameter should be used in the calculation.

Annex JA (informative)

List of the clauses of Part 1 and Part 2 applicable to the equipment using AOPDs

Introduction

This Annex is to list up in an easy-to-understand format the clauses of **JIS B 9704** Part 1 and Part 2 applicable to the equipment using AOPDs and not to constitute the provisions of this Standard.

The requirements applicable to the equipment using AOPDs become complete specification by a combination of the part of provisions in Part 1 (**JIS B 9704-1** : 2006) applied as it is (not stated in this Standard) and all the parts specified in this Standard.

JA.1 List

The table below shows all the clause numbers and titles of **JIS B 9704** Part 1 and Part 2 applicable to the equipment using AOPDs. The shaded region shows the clauses applicable to ESPE employing AOPDs (The clauses with only title are not shaded because of containing no provisions). “-1” and “-2” in the right most column mean “Part 1” and “Part 2” respectively.

| Provisions in Part 1 | | Provisions in Part 2 (this Standard) | | Part applicable to AOPD |
|----------------------|------------------------------|--------------------------------------|--|-------------------------|
| Introduction | | Introduction | | -2 |
| 1 | Scope | 1 | Scope (<i>Replacement</i>) | -2 |
| 2 | Normative references | 2 | Normative references (<i>Partial addition</i>) | -1 and -2 |
| 3 | Terms and definitions | 3 | Terms and definitions | — |
| 3.1 to 3.2 | | | | -1 |
| 3.3 | Detection capability | 3.3 | Detection capability (<i>Replacement</i>) | -2 |
| 3.4 to 3.33 | | | | -1 |
| | | 3.201 | active opto-electronic protective device (AOPD) (<i>Addition</i>) | -2 |
| | | 3.202 | beam-centre line (<i>Addition</i>) | -2 |
| | | 3.203 | effective aperture angle (EAA) (<i>Addition</i>) | -2 |
| | | 3.204 | light beam device (<i>Addition</i>) | -2 |
| | | 3.205 | light curtain (<i>Addition</i>) | -2 |
| | | 3.206 | test piece (<i>Addition</i>) | -2 |
| | | 3.207 | monitored blanking (<i>Addition</i>) | -2 |

| Provisions in Part 1 | | Provisions in Part 2 (this Standard) | | Part applicable to AOPD |
|----------------------|--|--------------------------------------|--|-------------------------|
| 4.3 | Environmental requirements | 4.3 | Environmental requirements <i>(Addition)</i> | -2 |
| 4.3.1 | Ambient air temperature range and humidity | | | -1 |
| 4.3.2 | Electrical disturbances | | | -1 |
| 4.3.2.1 | Power supply voltage variations | | | -1 |
| 4.3.2.2 | Supply voltage interruptions | | | -1 |
| 4.3.2.3 | Fast transient/burst | | | -1 |
| 4.3.2.3.1 | General requirements | | | -1 |
| 4.3.2.3.2 | Additional requirements | | | -1 |
| 4.3.2.4 | Fast transient/surge | | | -1 |
| 4.3.2.4.1 | General requirements | | | -1 |
| 4.3.2.4.2 | Additional requirements | | | -1 |
| 4.3.2.5 | Electromagnetic field | | | -1 |
| 4.3.2.5.1 | General requirements | | | -1 |
| 4.3.2.5.2 | Additional requirements | | | -1 |
| 4.3.2.6 | Conducted disturbances induced by radio-frequency fields | | | -1 |
| 4.3.2.6.1 | General requirements | | | -1 |
| 4.3.2.6.2 | Additional requirements | | | -1 |
| 4.3.2.7 | Electrostatic discharge | | | -1 |
| 4.3.2.7.1 | General requirements | | | -1 |
| 4.3.2.7.2 | Additional requirements | | | -1 |
| 4.3.3 | Mechanical environment | | | -1 |
| 4.3.3.1 | Vibration | | | -1 |
| 4.3.3.2 | Bump | | | -1 |
| 4.3.4 | Enclosure | | | -1 |
| | | 4.3.5 | Light interference <i>(Addition)</i> | -2 |

| Provisions in Part 1 | | Provisions in Part 2 (this Standard) | | Part applicable to AOPD |
|----------------------|--|--------------------------------------|---|-------------------------|
| 5 | Testing | 5 | Testing | — |
| 5.1 | General | 5.1 | General (<i>Partial addition</i>) | -1 and -2 |
| 5.1.1 | Type tests | 5.1.1 | Type tests | — |
| 5.1.1.1 | ESPE for test | | | -1 |
| 5.1.1.2 | Operating condition | 5.1.1.2 | Operating condition (<i>Partial addition</i>) | -1 and -2 |
| 5.1.1.3 | Simulated intrusion into detection zone | | | -1 |
| 5.1.2 | Test conditions | 5.1.2 | Test conditions | — |
| 5.1.2.1 | Test environment | | | -1 |
| 5.1.2.2 | Measurement accuracy | 5.1.2.2 | Measurement accuracy (<i>Partial addition</i>) | -1 and -2 |
| 5.1.3 | Test results | | | -1 |
| 5.2 | Functional tests | 5.2 | Functional tests | — |
| 5.2.1 | Sensing function | 5.2.1 | Sensing function and detection capability (<i>Replacement</i>) | -2 |
| | | 5.2.1.1 | Sensing function (<i>Replacement of sub-clause</i>) | -2 |
| | | 5.2.1.2 | Integrity of the AOPD detection capability (<i>Replacement of sub-clause</i>) | -2 |
| | | 5.2.1.3 | Additional tests for an AOPD using retro-reflective techniques (<i>Replacement of subclause</i>) | -2 |
| | | 5.2.1.4 | Additional tests for an AOPD using emitters and receivers in the same assembly (<i>Replacement of subclause</i>) | -2 |
| 5.2.2 | Response time | | | -1 |
| 5.2.3 | Limited functional tests | | | -1 |
| 5.2.3.1 | General | | | -1 |
| 5.2.3.2 | Limited functional test A (A test) | | | -1 |
| 5.2.3.3 | Limited functional test B (B test) | | | -1 |
| 5.2.3.4 | Limited functional test C (C test) | | | -1 |

| Provisions in Part 1 | | Provisions in Part 2 (this Standard) | | Part applicable to AOPD |
|----------------------|--|--------------------------------------|--|-------------------------|
| 5.2.4 | Periodic test | | | -1 |
| 5.2.5 | Indicator lights and displays | | | -1 |
| 5.2.6 | Means of adjustment | | | -1 |
| 5.2.7 | Rating of components | | | -1 |
| 5.2.8 | Output signal switching devices (OSSD) | | | -1 |
| 5.2.8.1 | General | | | -1 |
| 5.2.8.2 | Relay OSSDs | | | -1 |
| 5.2.8.3 | Solid state OSSDs | | | -1 |
| | | 5.2.9 | Verification of optical performance <i>(Addition)</i> | -2 |
| | | 5.2.9.1 | Analysis of the electro-optical sub-system <i>(Addition)</i> | -2 |
| | | 5.2.9.1.1 | Analysis <i>(Addition)</i> | -2 |
| | | 5.2.9.1.2 | Selection of test method <i>(Addition)</i> | -2 |
| | | 5.2.9.2 | Side lobe and misalignment test (Measurement of EAA) <i>(Addition)</i> | -2 |
| | | 5.2.10 | Wavelength <i>(Addition)</i> | -2 |
| | | 5.2.11 | Radiation intensity <i>(Addition)</i> | -2 |
| 5.3 | Performance testing under fault condition | | | -1 |
| 5.3.1 | General | | | -1 |
| 5.3.2 | Type 1 ESPE Verification | | | -1 |
| 5.3.3 | Type 2 ESPE Verification | | | -1 |
| 5.3.4 | Type 3 ESPE Verification | | | -1 |
| 5.3.5 | Type 4 ESPE Verification | | | -1 |
| 5.4 | Environmental tests | 5.4 | Environmental tests | — |
| 5.4.1 | Rated power supply voltage | | | -1 |
| 5.4.2 | Ambient temperature variation and humidity | | | -1 |

| Provisions in Part 1 | | Provisions in Part 2 (this Standard) | | Part applicable to AOPD |
|----------------------|--|--------------------------------------|---|-------------------------|
| 5.4.3 | Effects of electrical disturbances | | | -1 |
| 5.4.3.1 | Power supply voltage variations | | | -1 |
| 5.4.3.2 | Supply voltage interruptions | | | -1 |
| 5.4.3.3 | Fast transient/burst | | | -1 |
| 5.4.3.3.1 | General requirements | | | -1 |
| 5.4.3.3.2 | Additional tests | | | -1 |
| 5.4.3.4 | Fast transient/surge | | | -1 |
| 5.4.3.4.1 | General requirements | | | -1 |
| 5.4.3.4.2 | Additional tests | | | -1 |
| 5.4.3.5 | Electromagnetic field | | | -1 |
| 5.4.3.5.1 | General tests | | | -1 |
| 5.4.3.5.2 | Additional tests | | | -1 |
| 5.4.3.6 | Conducted disturbances induced by radio-frequency fields | | | -1 |
| 5.4.3.6.1 | General tests | | | -1 |
| 5.4.3.6.2 | Additional tests | | | -1 |
| 5.4.3.7 | Electrostatic discharge | | | -1 |
| 5.4.3.7.1 | General tests | | | -1 |
| 5.4.3.7.2 | Additional tests | | | -1 |
| 5.4.4 | Mechanical influences | | | -1 |
| 5.4.4.1 | Vibration | | | -1 |
| 5.4.4.2 | Bump | | | -1 |
| 5.4.5 | Enclosures | | | -1 |
| | | 5.4.6 | Light interference (Addition) | -2 |
| | | 5.4.6.1 | General (Addition) | -2 |
| | | 5.4.6.2 | Light sources (Addition) | -2 |
| | | 5.4.6.3 | Test sequences (Addition) | -2 |
| | | 5.4.6.4 | Normal operation (best alignment) (Addition) | -2 |
| | | 5.4.6.5 | Failure to danger— Incandescent light (3 000 lx and worst- case alignment) (Addition) | -2 |

| Provisions in Part 1 | | Provisions in Part 2 (this Standard) | | Part applicable to AOPD |
|----------------------|--|--------------------------------------|---|-------------------------|
| | | 5.4.6.6 | Failure to danger— Stroboscopic light (worst-case alignment) <i>(Addition)</i> | -2 |
| | | 5.4.6.7 | Failure to danger— Fluorescent light (3 000 lx and worst- case alignment) <i>(Addition)</i> | -2 |
| | | 5.4.6.8 | Failure to danger— Interfering light from an emitting element of identical design <i>(Addition)</i> | -2 |
| 5.5 | Validation of program- mable or complex integrated circuits | | | -1 |
| 5.5.1 | General | | | -1 |
| 5.5.2 | Complex or program- mable integrated circuits | | | -1 |
| 5.5.3 | Software, program- ming, functional design of integrated circuits | | | -1 |
| 5.5.4 | Test results analysis statement | | | -1 |
| 6 | Marking for identifi- cation and for safe use | 6 | Marking for identifi- cation and for safe use | — |
| 6.1 | General | 6.1 | General <i>(Partial addi- tion)</i> | -1 and -2 |
| 6.2 | ESPE supplied from a dedicated power supply | | | -1 |
| 6.3 | ESPE supplied from an internal electrical power source | | | -1 |
| 6.4 | Adjustment | | | -1 |
| 6.5 | Enclosures | | | -1 |
| 6.6 | Control devices | | | -1 |
| 6.7 | Terminal markings | | | -1 |
| 6.8 | Marking durability | | | -1 |
| 7 | Accompanying docu- ments | 7 | Accompanying docu- ments <i>(Partial addition)</i> | -1 and -2 |

| Provisions in Part 1 | | Provisions in Part 2 (this Standard) | | Part applicable to AOPD |
|---------------------------------|--|--------------------------------------|---|-------------------------|
| Annex A (normative) | Optional functions of the ESPE | Annex A (normative) | Optional functions of the ESPE (<i>Partial addition</i>) | -1 and -2 |
| Annex B (normative) | Catalogue of single faults affecting the electrical equipment of the ESPE, (to be considered as failure to danger in 5.3) | Annex B (normative) | Catalogue of single faults affecting the electrical equipment of the ESPE, (to be applied as specified in 5.3) | -1 |
| Annex C (informative) | Conformity assessment | | | -1 |
| | | Annex D (normative) | Verifying effective aperture angle (EAA) using the prism method (<i>Addition</i>) | -2 |
| | | Annex E (normative) | Verifying optical performance using the mirror method and misalignment test (<i>Addition</i>) | -2 |
| | | Annex F (informative) | AOPD detection capability based on complete obscuration (<i>Addition</i>) | -2 |

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Standards Publishing Department, Japanese Standards Association

4-1-24, Akasaka, Minato-ku, Tokyo, 107-8440 JAPAN

TEL. 03-3583-8002 FAX. 03-3583-0462